Intellectual Output 2 – IO.2

Students' Teaching Module

Unit 4. Ecological Footprint Introduction

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Enhancing Universities' Sustainability TEaching and Practices through Ecological Footprint

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Global Footprint Network® Advancing the Science of Sustainability

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Unit 4. Ecological Footprint Introduction

Basics of the Ecological Footprint, main equations, trends and results around the world, and related indicators

a- slides

Photo by Annie Spratt on Unsplash

Rendering society-environment relations researchable - What can we measure, and what are the risks?

But …… why should we measure?

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Introducing Footprint Indicators

- Since the turn of the 21st century, the term "footprint" has become very popular and entered in our daily vocabulary as a metaphor for the impact humans place on the Environment.
- Such metaphoric meaning of the term dates back to the early 1990s and has its origins in the birth of a specific methodology called "Ecological Footprint."

The New York Times Magazine

Magazine | ON LANGUAGE

Footprint

By WILLIAM SAFIRE FEB. 17, 2008

"**The word *footprint*** has taken on meaning," writes Michel Berger of Oakland, Calif., responding to a recent query in this space, "beyond that of simple circumstantial evidence that someone has walked by, as in Daniel Defoe's 1719 novel 'Robinson Crusoe.' Where are those footprints headed?"

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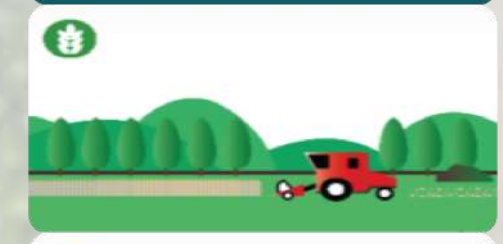
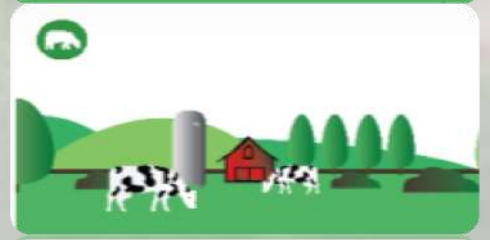
Built-up areas infrastructures

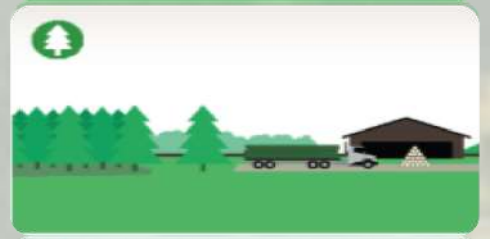
Carbon sequestration



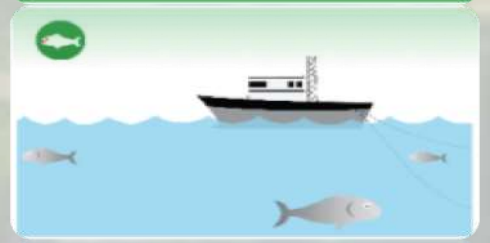
Cropland



Grazing land



Forest land



Fishing grounds

THE STORY OF TODAY

DAILY ECOLOGICAL FOOTPRINT

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Why EF…?

daily

EF = 125 m^2

MY INDIVIDUAL ECOLOGICAL FOOTPRINT

EF = 4.5 hectares

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BUT……I AM NOT ALONE ON THIS PLANET…

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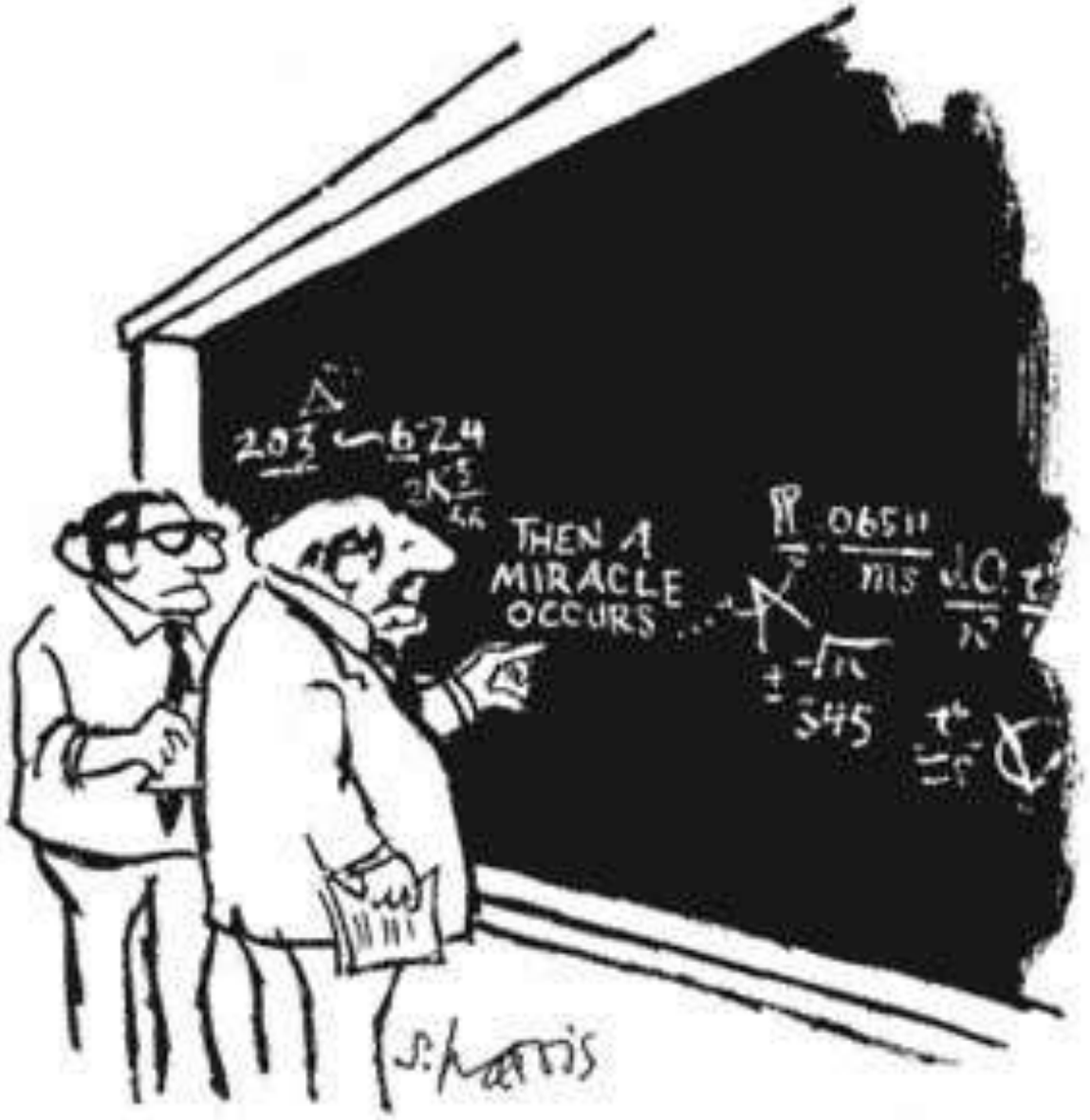
I AM SHARING IT WITH ABOUT OTHER 7.8 BILLION PEOPLE!!!

What is the Ecological Footprint?



"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."

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ECOLOGICAL FOOTPRINT:
An Ecological Balance Sheet For Countries

The Ecological Footprint is an environmental accounting tool that identifies the extent to which human activities exceed **two types of environmental limits:**

- resource production
- waste absorption

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THE ECOLOGICAL FOOTPRINT

The Ecological Footprint measures the amount of biologically productive land and water (fishing grounds) area required to:

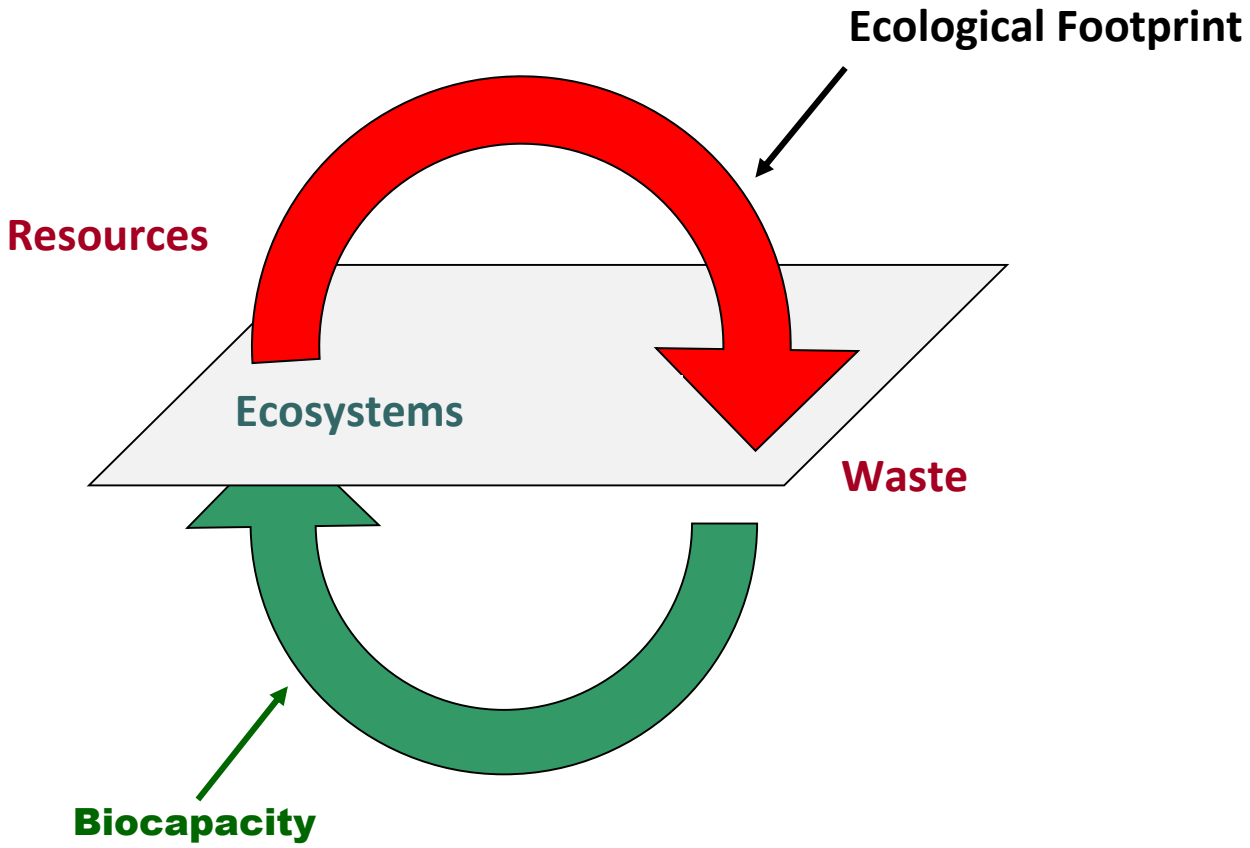
- produce all the resources an individual, population or activity consumed
- to absorb the wastes they generated, given prevailing technology and resources management practices.

The final Ecological Footprint of an individual or a country is the sum of all these different types of land, irrespective of where they are located.

(Wackernagel and Rees, 1996)

Societies use resources (food, energy, etc.) and produce wastes.

ECOLOGICAL FOOTPRINT: An Ecological Balance Sheet For Countries



Nature turns wastes back into resources

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BIOCAPACITY

- Measures the amount of biologically productive land and sea area available to provide the ecosystem services that humanity consumes.

- The biocapacity represents the natural capital that provides the basic life-support services, expressed as the available regenerative capacity of the biosphere.

- The biocapacity represents the ability of the biosphere to produce crops, timber, livestock as well as to absorb carbon dioxide.

- The total biocapacity of a Nation (or planet) is calculated as the sum of the biocapacity supplied by each land type.

- It depends on natural conditions but also on dominant agriculture and forestry practices.

ECOLOGICAL FOOTPRINT: ASSESSING COUNTRIES' ECOLOGICAL BALANCE

Biocapacity:
*How much bioproductive area is **available to us**?*

Ecological Footprint:
*How much bioproductive area do we **demand**?*

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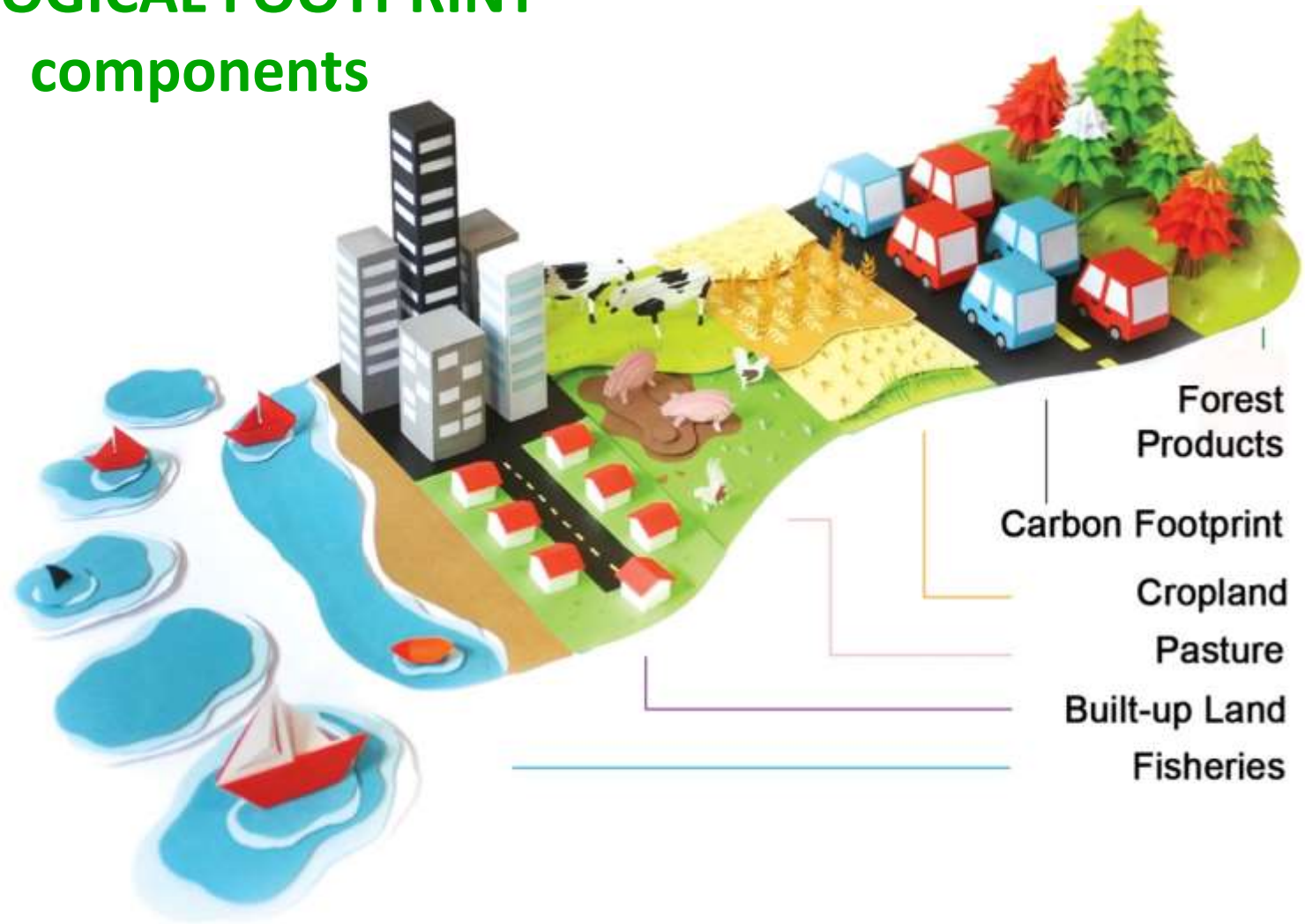
ECOLOGICAL FOOTPRINT components



CARBON
CO2 emissions associated with use of fossil fuels, electricity and energy intensive commodities, converted into biologically productive areas (such as forest land) necessary for their sequestration.

GRAZING LAND
The area of grasslands used to raise livestock for meat, diary, hide and wool products. It includes all grassands used to provide feed for animals, including cultivated pastures, wild grasslands and prairies.

FOREST
The area of forests required to support the annual harvest of fuel wood, pulp and timber products.

FISHING GROUNDS
The area of marine and inland waters required to support annual catches of aquatic species (fish and seafood).

CROPLAND
The area required to grow all crop products required for human consumption (food and fiber) and for livestock feeds, fish meals, oil crops and rubber.

BUILT-UP LAND
The area of land covered by human infrastructure such as transportation, housing, industrial structures and reservoirs for hydroelectric power generation.

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The Ecological Footprint is a flows indicator, though it is measured in terms of the bioproductive land areas needed to generate such flows (expressed in the unit of global hectares - gha).

$$EF = \frac{P}{Y_N} \cdot YF \cdot EQF$$

Input variable: flow of resource used by humans

From FLOW to AREA :

- Y_N is used to convert the consumption of a resource flow into the correspondent amount of area locally required to produce that flow
- **YF** is used to scale national to world average productivity for a given land use type
- **EQF** is used to scale world average productivity for a given land type to gha.

$$BC = A \cdot YF \cdot EQF$$

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Biocapacity

Ecological Footprint

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Unit: hectare-equivalent or Global hectare

The Ecological Footprint is an indicator of human appropriation of Earth's photosynthetic capacity, although expressed in hectare-equivalents.

The release of 1 t of CO_{2eq} does not mean that this amount has actually been released (no molecule called CO_{2eq}). Rather, it means that various GHGs with the equivalent global warming potential of 1 t of CO_2 have been released.

Similarly, having a per capita Ecological Footprint of 1 gha doesn't mean that 1 ha of physical land are used. It rather means that the capacity of 1 hectare-equivalents (or gha) is needed to produce (via photosynthesis) the renewable resource provisioning services consumed and to sequester the carbon dioxide emitted

Unit: hectare-equivalent or Global hectare

Fore example, if this hectare is twice as productive as a world average, biologically productive hectare. Then it is worth 2 gha.

→

2 gha

For example, if this hectare is half as productive as a world average, biologically productive hectare. Then it is worth ½ a gha.

→

½ gha

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ECOLOGICAL FOOTPRINT: SCALE OF APPLICATION

Various methodological approaches but same rationale

Countries and regions

World | Humanity

Cities

Individuals

Ecological Footprint allows looking and acting locally in the context of the global situation

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Looking at the Earth as a single system: Showing our society's overall direction

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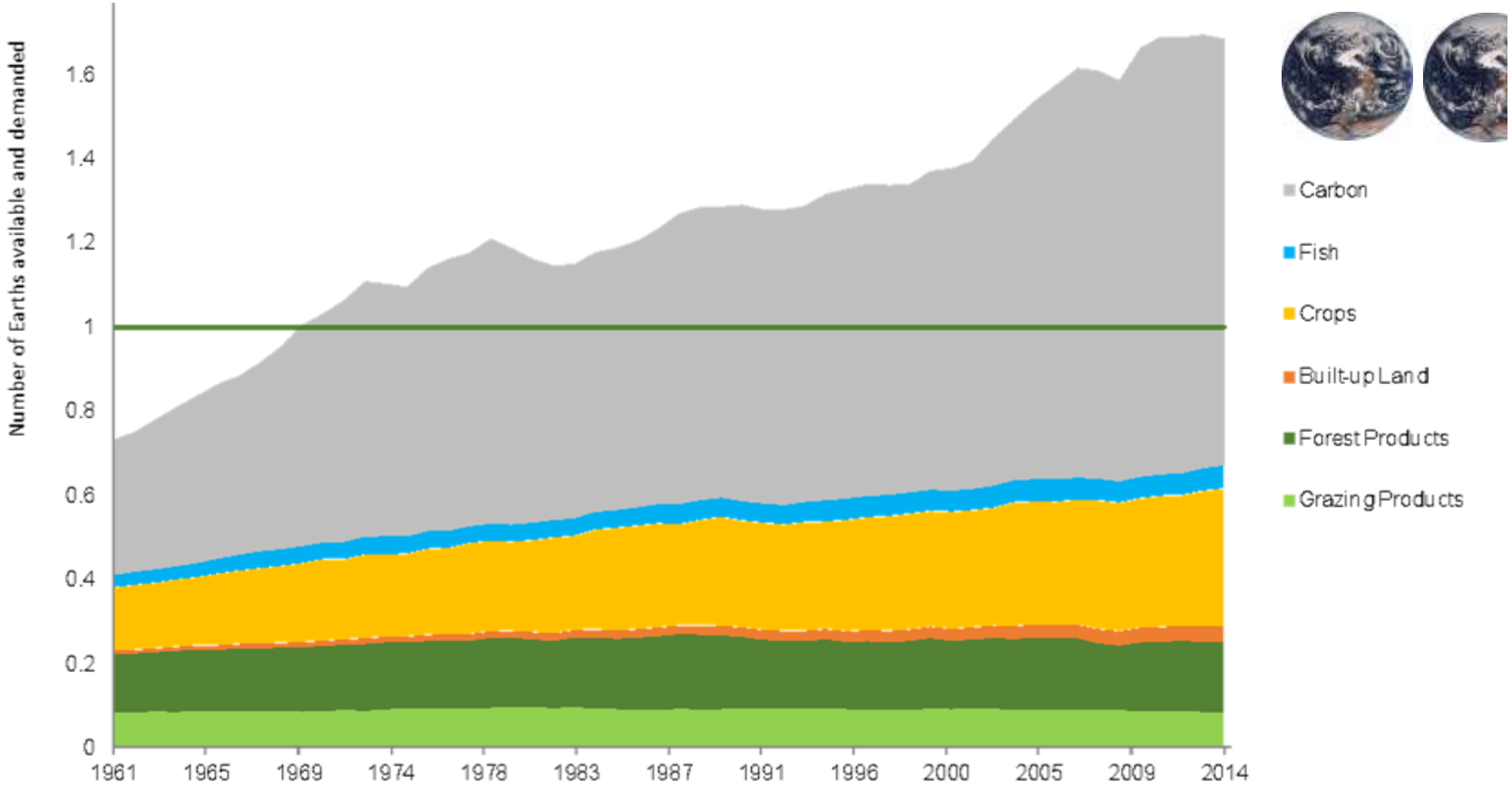
Humanity's Ecological Footprint and biocapacity, 1961 – 2014



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NATIONAL FOOTPRINT ACCOUNTS FRAMEWORK

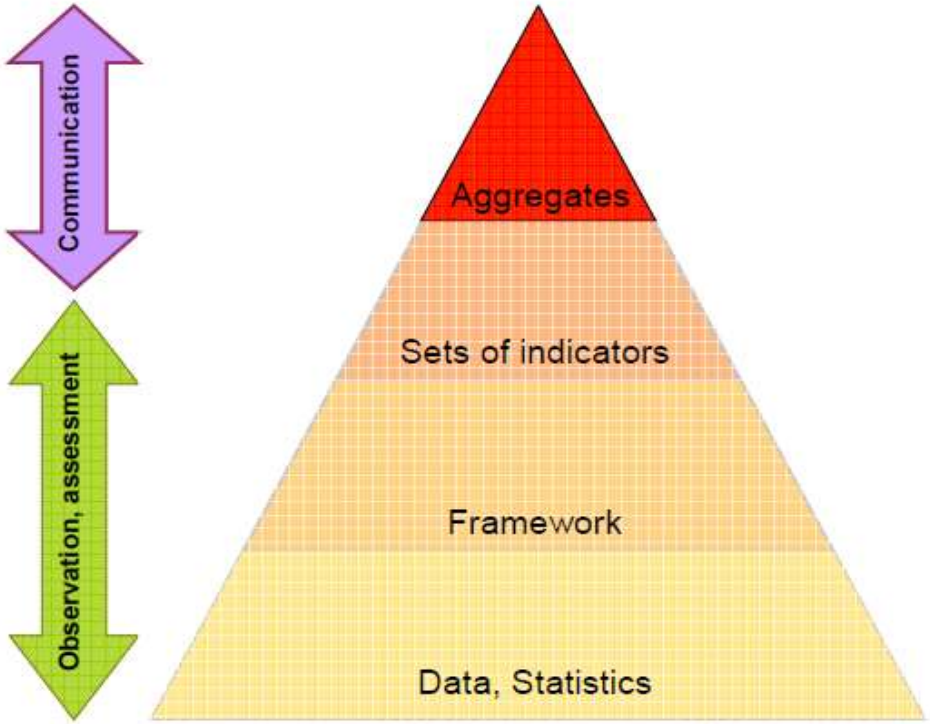

Figure 3: Pyramid structure of the National Footprint Accounts (NFA). All levels of the pyramid exist in the NFA, potentially allowing for both system's description and support to policy makers. However, data used and the framework in place are not fully consistent with SNA and SEEA (transparent colors are used here to represent this not full consistency). *Source: adapted from Weber and Martin (2009).*

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EF_P

Production Activities:

-Agriculture
- Silviculture
- Farming
- Fishing
-Manifacturing
-etc

Imports

EF_I

$$EF_C = EF_P + (EF_I - EF_E)$$

BIOCAPACITY

EF_E

Exports

Global Footprint Network

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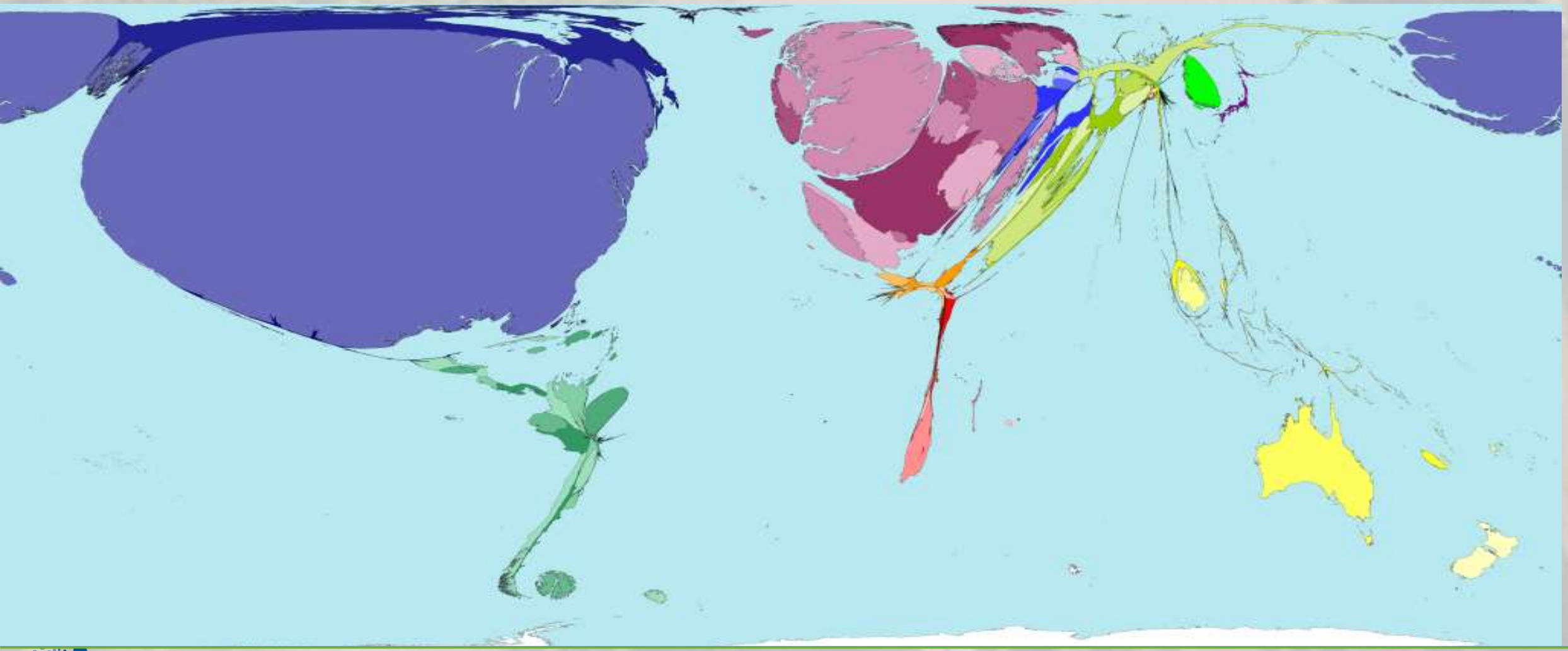
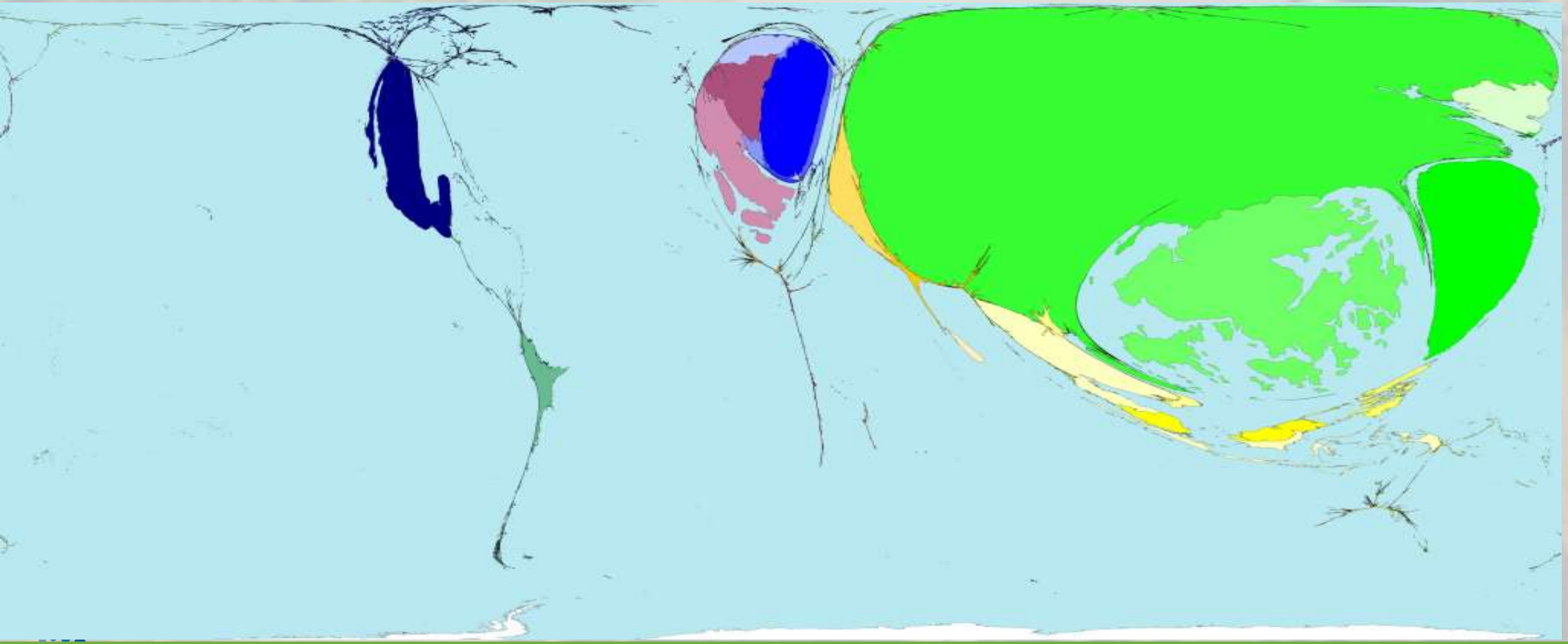
Why using a consumer approach?

Not everything that is consumed in the West…



World toy imports

… is being produced in the West. Environmental impacts are often manifesting far away from the places in which their root causes (i.e., their drivers) are taking place.



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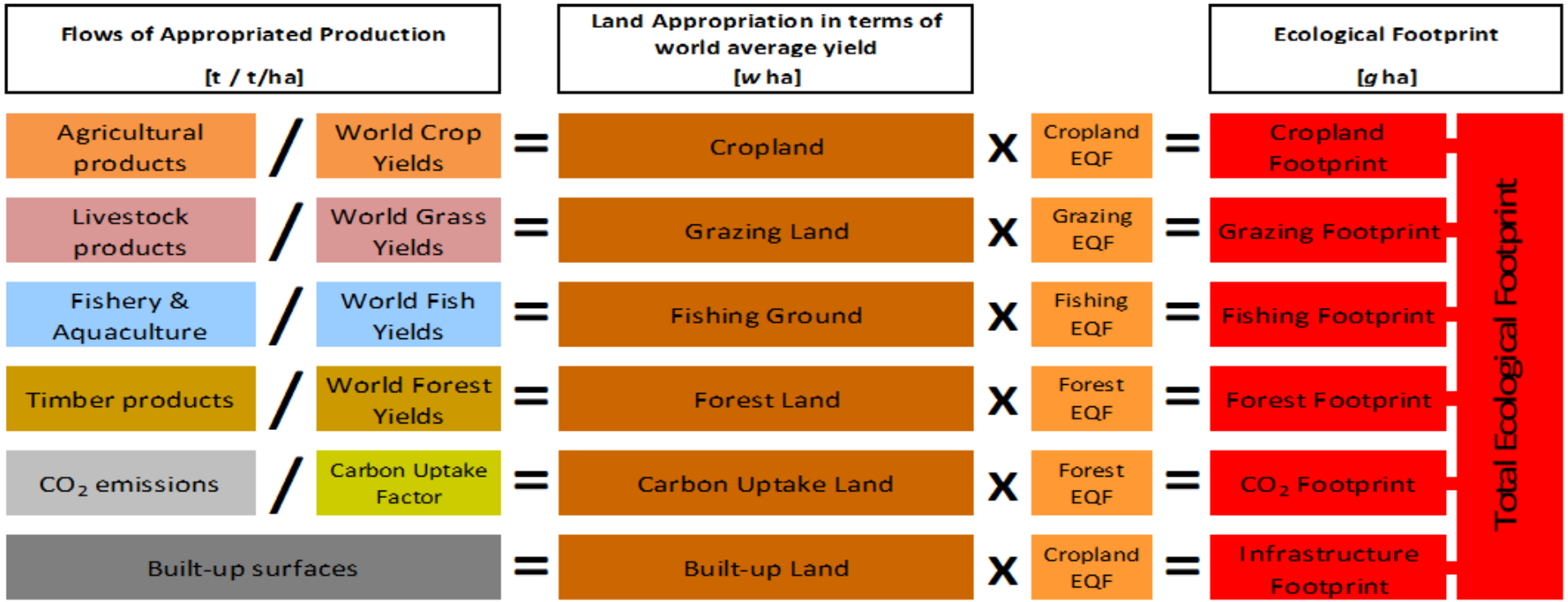
World toy exports

ECOLOGICAL FOOTPRINT



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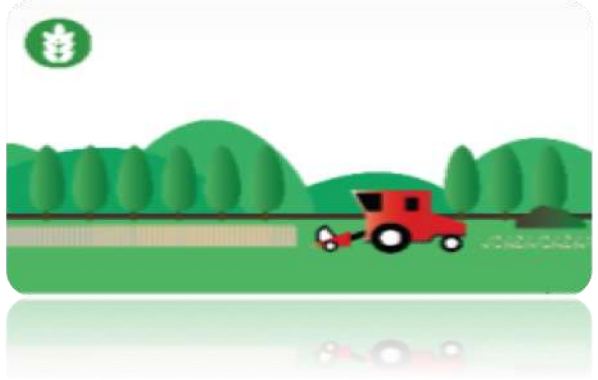
Ecological Footprint: input data



CROPLAND FOOTPRINT

Represents the area required to grow all crop products, including livestock feeds, fish feed, oil crops and rubber.

It is calculated by using data on production, import and export of ≈400 primary and derived agricultural products.

Source data is FAO

GRAZING LAND FOOTPRINT

Measures the area of grassland used in addition to crop feeds to provide feed for livestock, including cultivated pastures, wild grasslands and prairies.

It is calculated by using data on production, import and export of ≈150 animal and dairy products (including live animals).

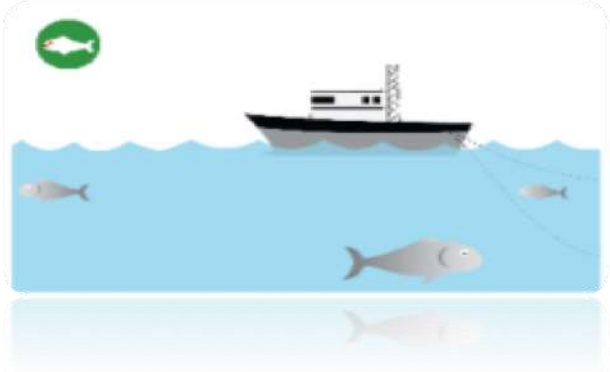
Source data is FAO

FOREST FOOTPRINT

Measures the annual harvest of fuel wood and timber to supply forest products.

It is calculated by using data on production, import and export of ≈30 in between timber and wood fuel products.

Source data is FAO

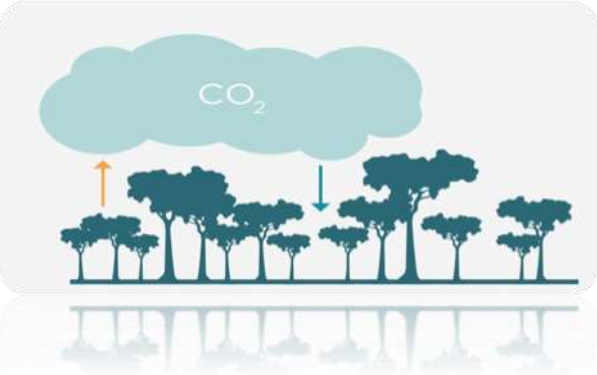


FISHING GROUNDS FOOTPRINT

Measures the area of marine and inland water used to provide the primary production needed to sustain aquatic species (including fish meals).

It is calculated by using data on production, import and export of ≈1500 fish products.

Source data is FAO

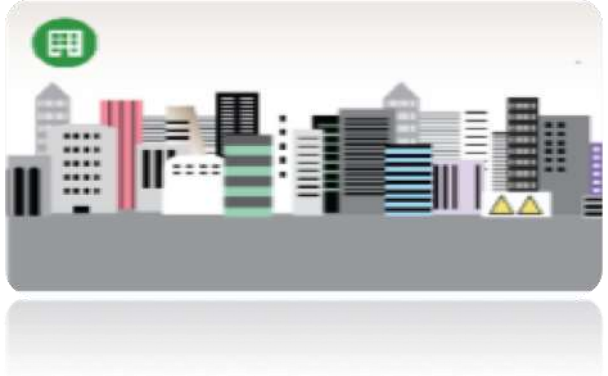


CARBON FOOTPRINT

Measures the uptake land to accommodate the carbon dioxide emissions due to consumption of fossil fuels, electricity and energy intensive products

It is calculated by using data on emissions from ≈45 industrial sectors as well as import and export of ≈625 manufactured commodities.

Source data is IEA and UN COMTADE

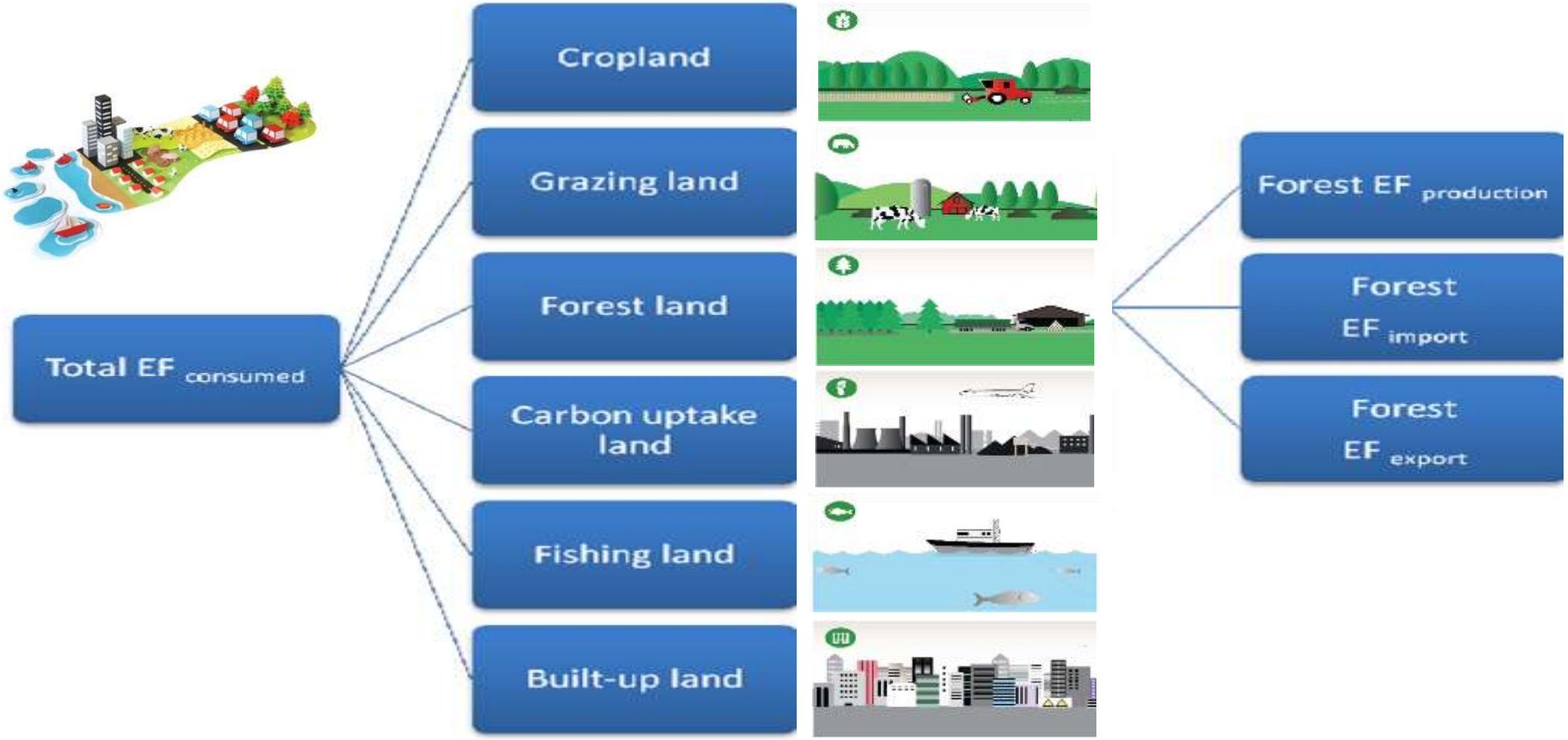


BUILT-UP LAND FOOTPRINT

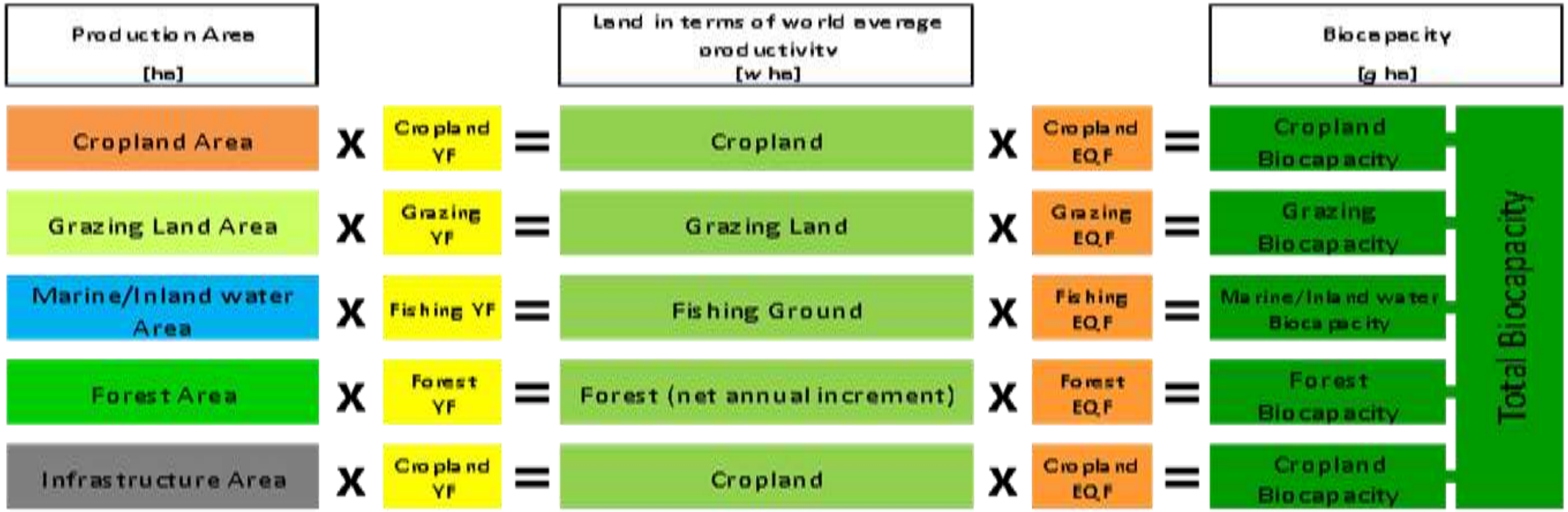
Measures the area of land covered by human infrastructure: transportation, housing, industrial structures and reservoirs for hydroelectric power generation.

Source data is CORINE, GLC, SAGE, etc

Ecological Footprint



BIOCAPACITY



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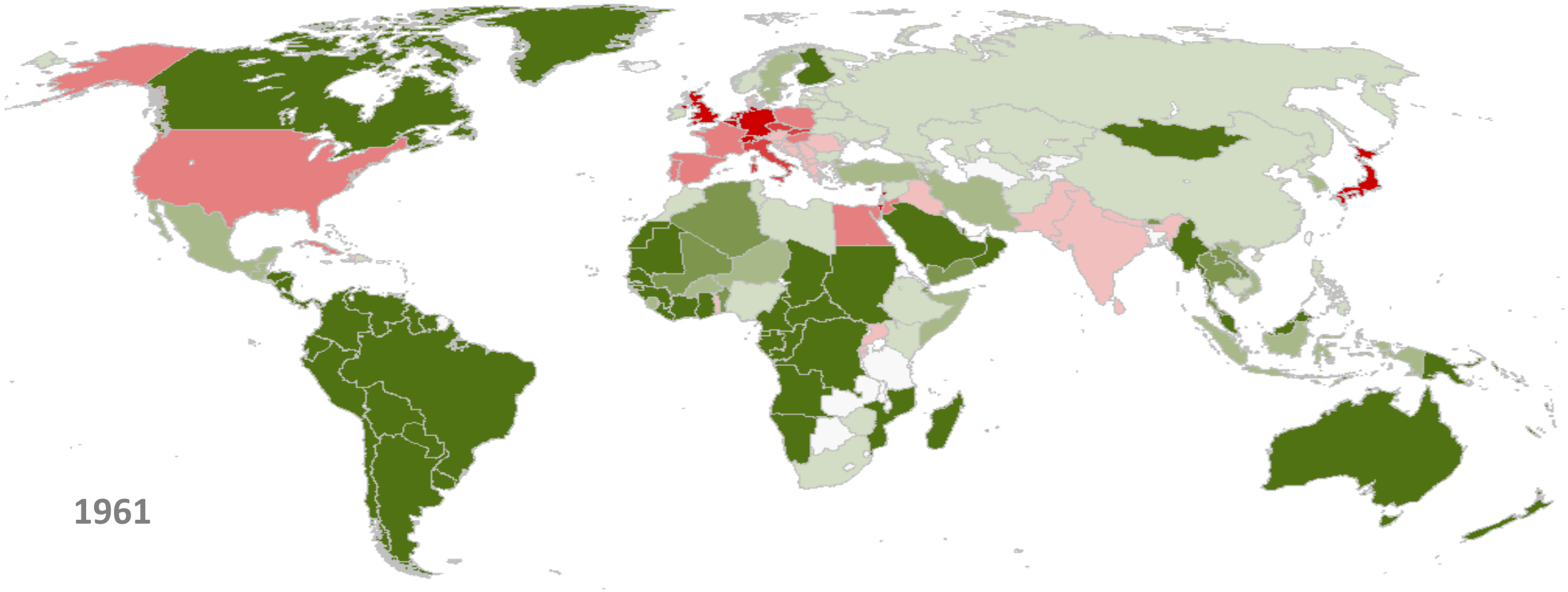
Outcomes: National Footprint Accounts - NFA

- **Every year** Global Footprint Network releases an updated version of the NFA, which is based on the most up-to-date Footprint methodology
- **Each edition** of the NFA tracks EF and BC values for almost 200 countries (and the World), over five decades (1961-2014) and with different level of aggregation:
    1. Aggregate national EF and BC values (most known)
    2. EF and BC values by land type
    3. EF values by variable
    4. EF values for all individual products
    5. Values are provided both per capita and total
    6. Results in both ha and gha (not for totals)

Global Footprint Network



1961

Ecological Footprint of consumption excceeds biocapacity

- > 150 %
- 100 - 150 %
- 50 - 100 %
- 0 - 50 %

Biocapacity exceeds Ecological Footprint of consumption

- 0 - 50 %
- 50 - 100 %
- 100 - 150 %
- >150 %

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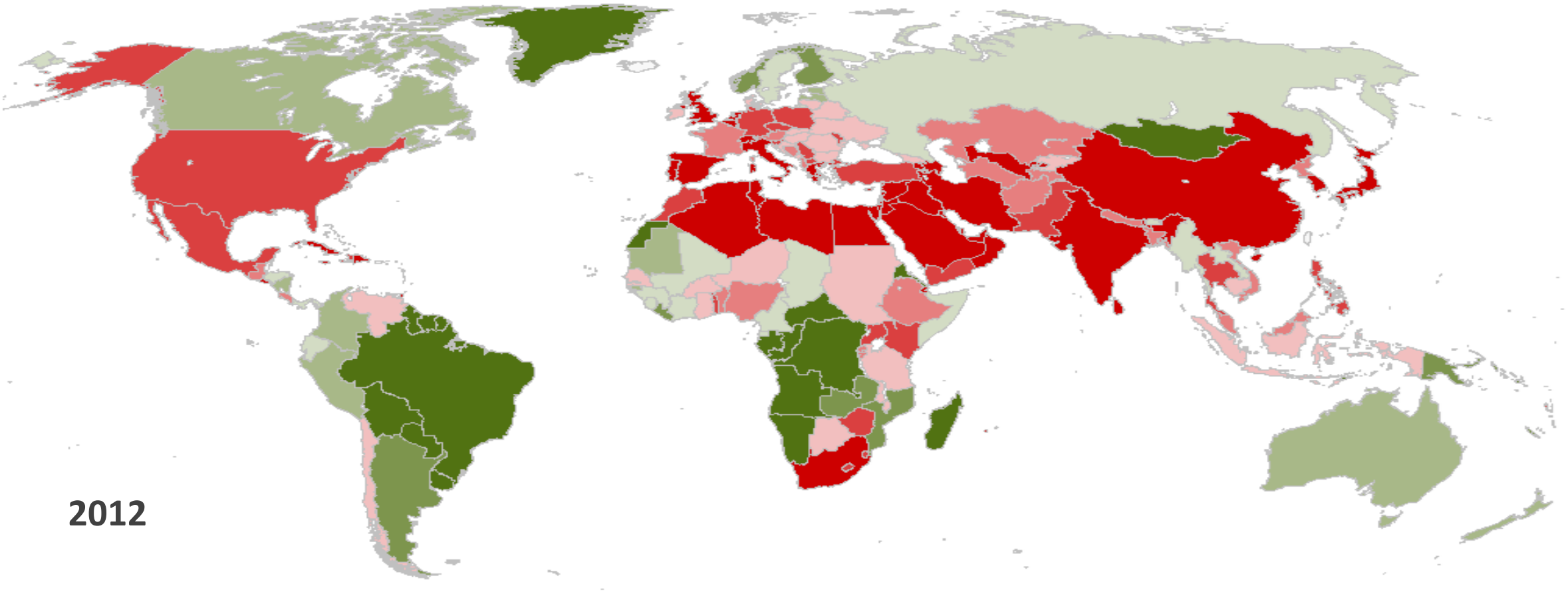
Data from the National Footprint Accounts 2016 Edition. www.footprintnetwork.org



2012

Ecological Footprint of consumption excceeds biocapacity

- > 150 %
- 100 - 150 %
- 50 - 100 %
- 0 - 50 %

Biocapacity exceeds Ecological Footprint of consumption

- 0 - 50 %
- 50 - 100 %
- 100 - 150 %
- >150 %

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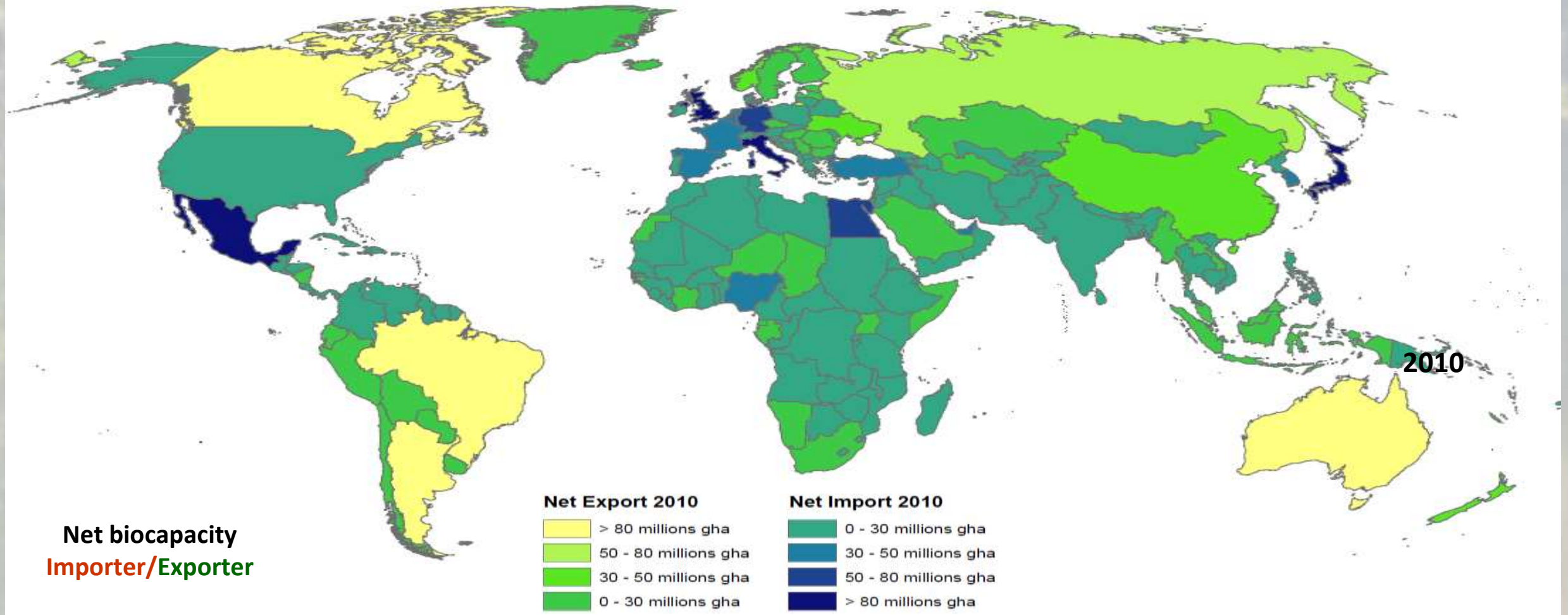
Data from the National Footprint Accounts 2016 Edition. www.footprintnetwork.org



Net biocapacity
Importer/Exporter

Countries are highly interconnected and depend on each other

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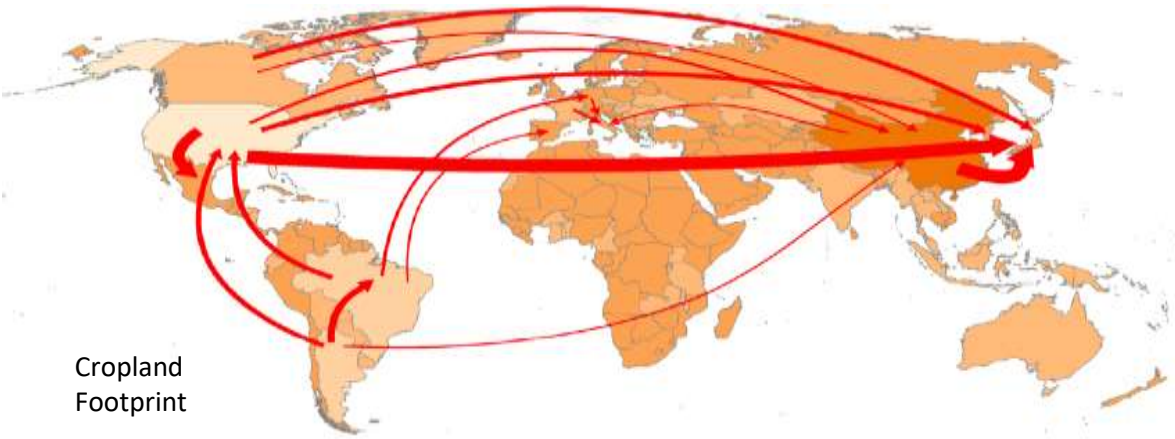
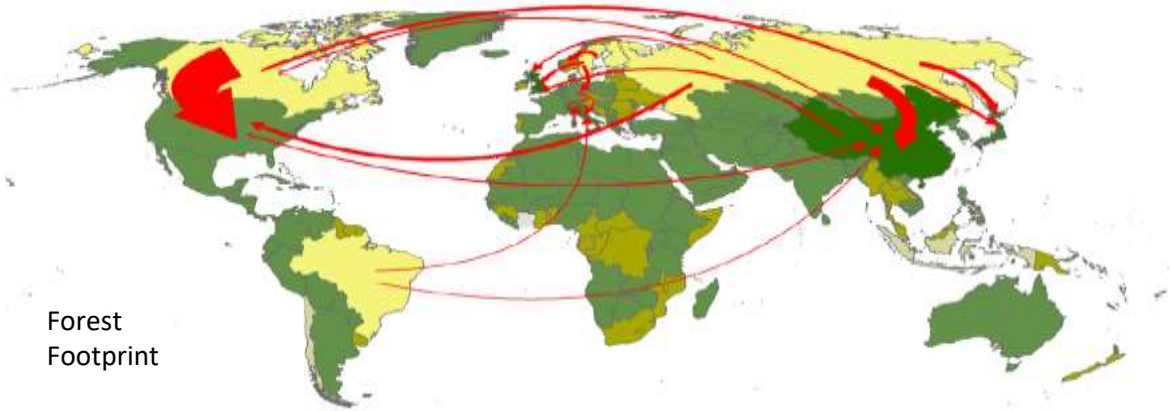
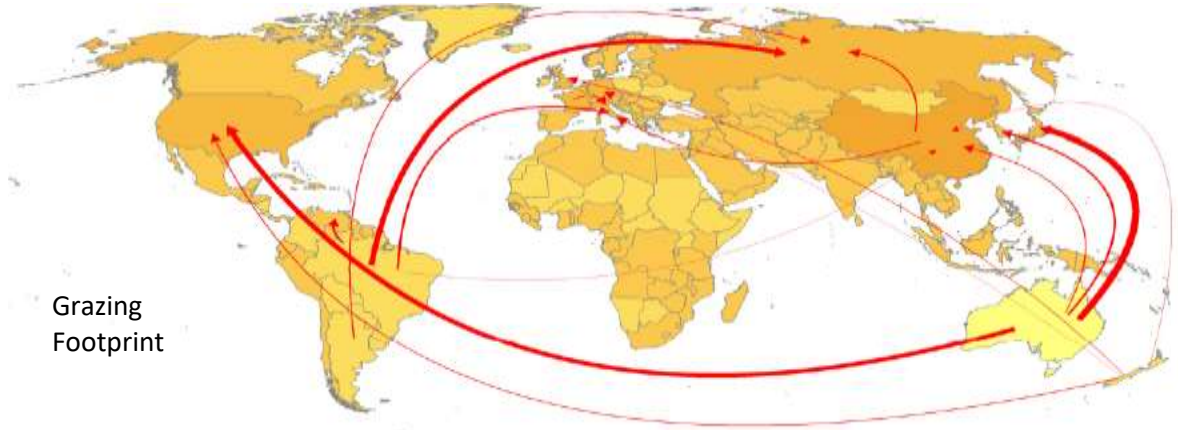
Source: Updated from Galli et al., 2014







Source: Lazarus et al, 2015

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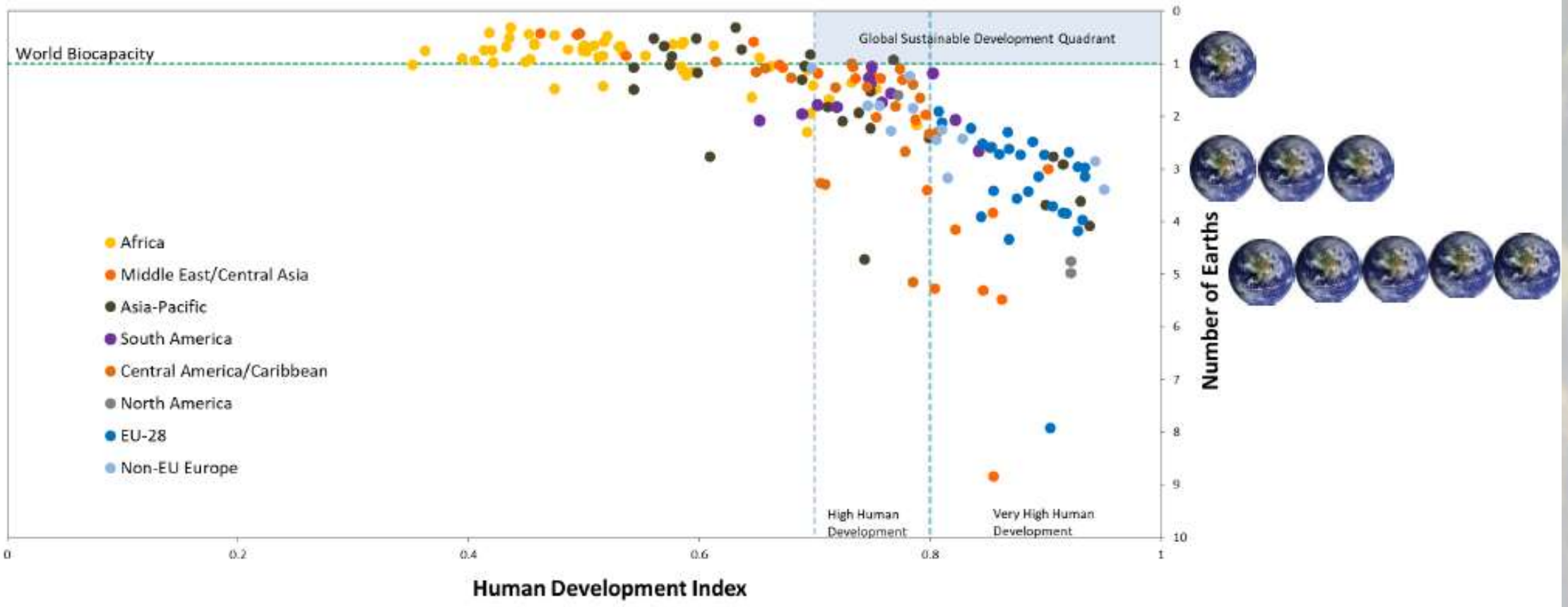
Ecological Footprint and Human Development Index of Countries (2016)



Source: Ecological Footprint (in number of Earths): National Footprint and Biocapacity Accounts, 2019 Edition, Global Footprint Network.
Human Development Index: Human Development Report, 2018, United Nations Development Programme.

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HOW MANY EARTHS?

If everybody had a Footprint like a quarter-finalist nation in the World Cup, how many Earths would it take to meet our demand on nature?

If everybody lived like Argentineans, it would take 1.6 Earths.

Humanity's Ecological Footprint by land type, 1961 – 2050

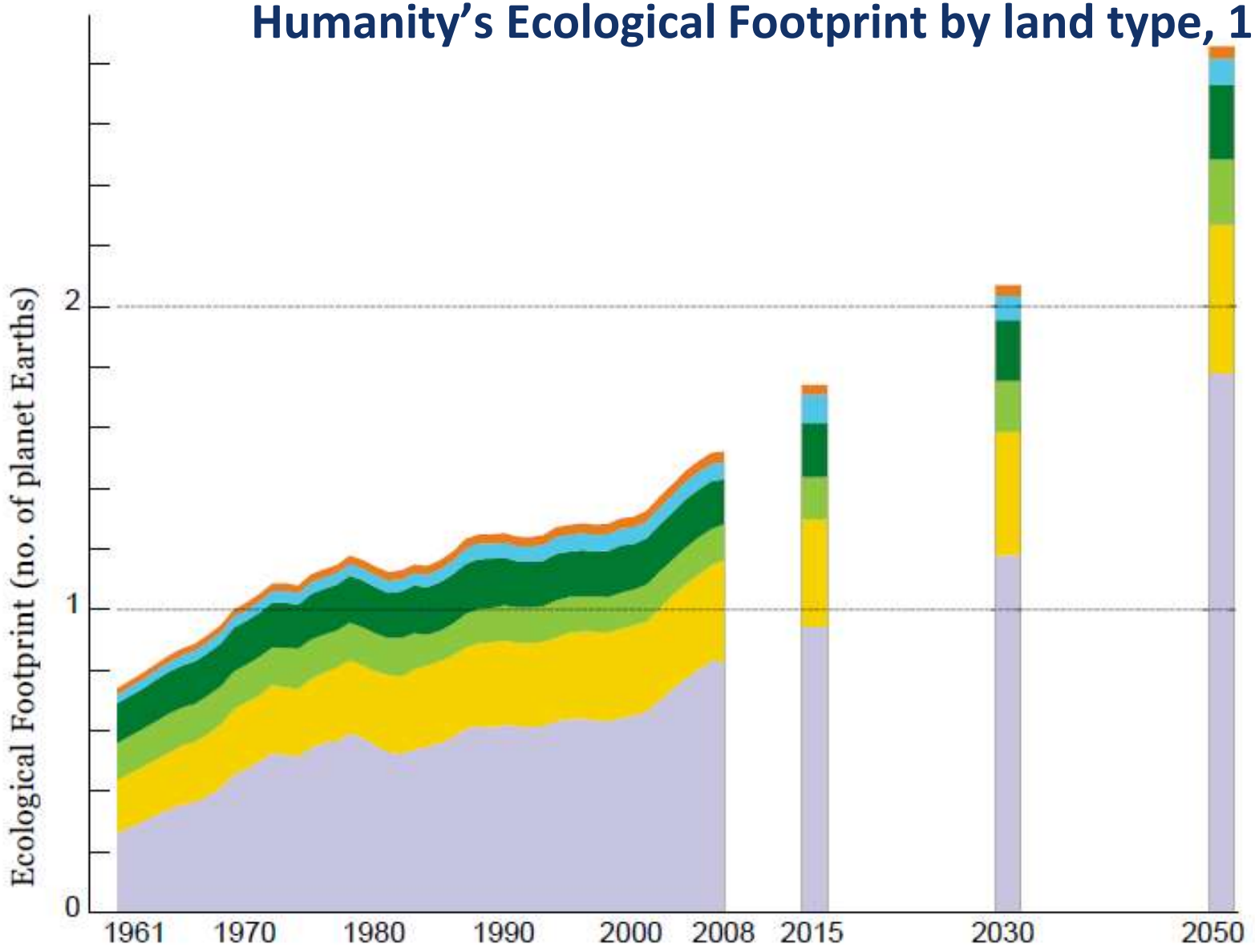

Figure 54: "Business as usual" scenario of the Ecological Footprint from 2009 to 2050

The Ecological Footprint scenario calculator uses trends from 1961 to 2008 to create a possible pathway up to 2050.

Key

- Built-up land
- Fishing
- Forest
- Grazing
- Cropland
- Carbon

Source: WWF, GFN, ZSL, Living Planet Report 2012.
Moore et al., 2012. Ecological Indicators 16, pp: 3-10.

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On the Usefulness of Ecological Footprint Accounting

WHAT WE LEARN FROM THIS? WHAT CAN WE DO?

- Globally, the human metabolism has become “faster” than the planet capacity to regenerate key resources and ecosystem services.
- This affects the health of ecosystems and biodiversity and puts at risk human well-being
- Countries around the world are telecoupled and overconsumption in a country causes resource depletion somewhere else
- As such, local resource management and governance cannot be blind to such global teleconnections and their consequences

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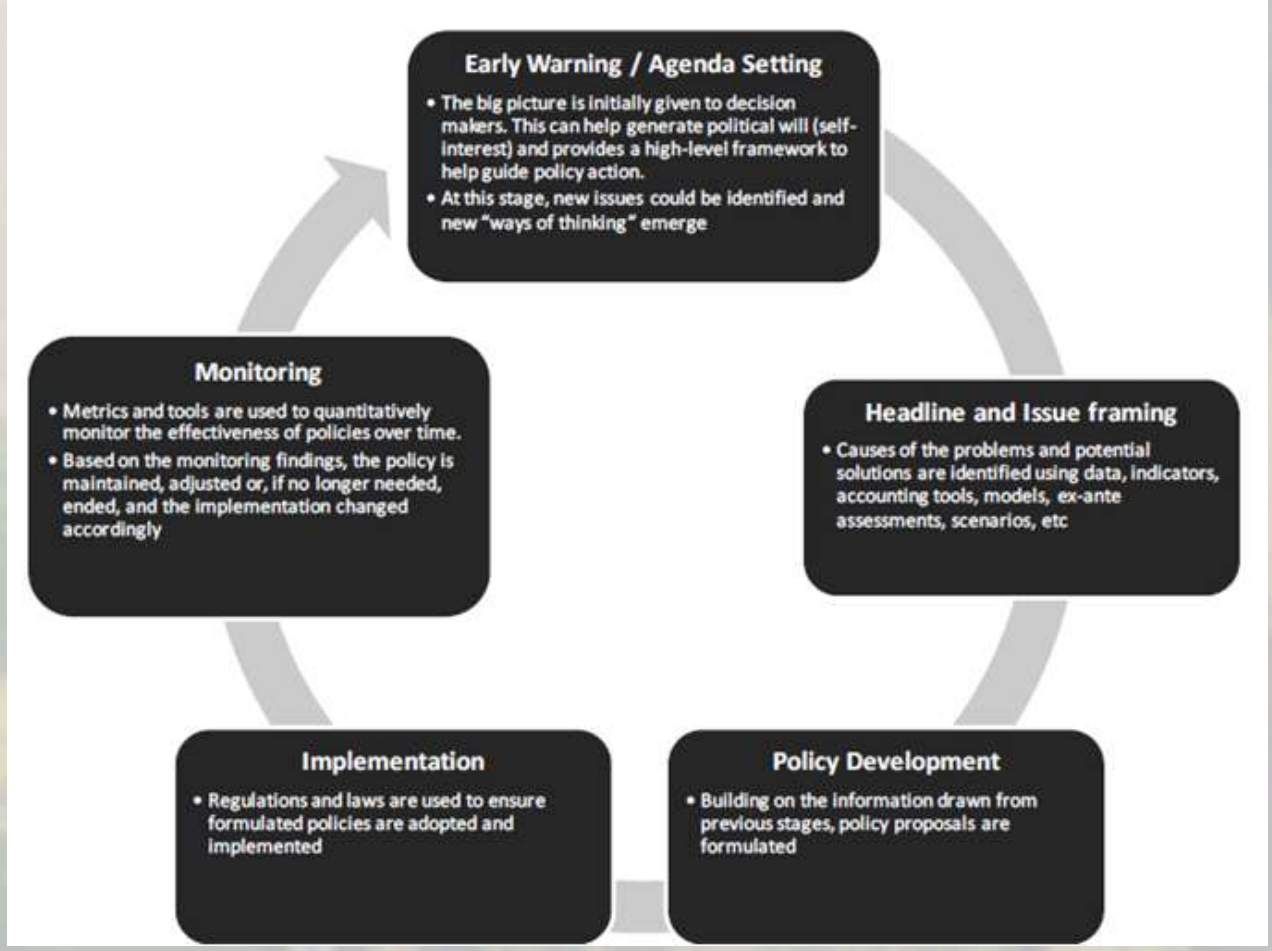
On the Usefulness of Ecological Footprint Accounting

•To assess the policy usefulness of the Ecological Footprint one first needs defining what policy useful means, what steps are involved in developing and implementing policies, and what information decision-makers need (compared with what a measure can provide) in each step of the policy formulation process.



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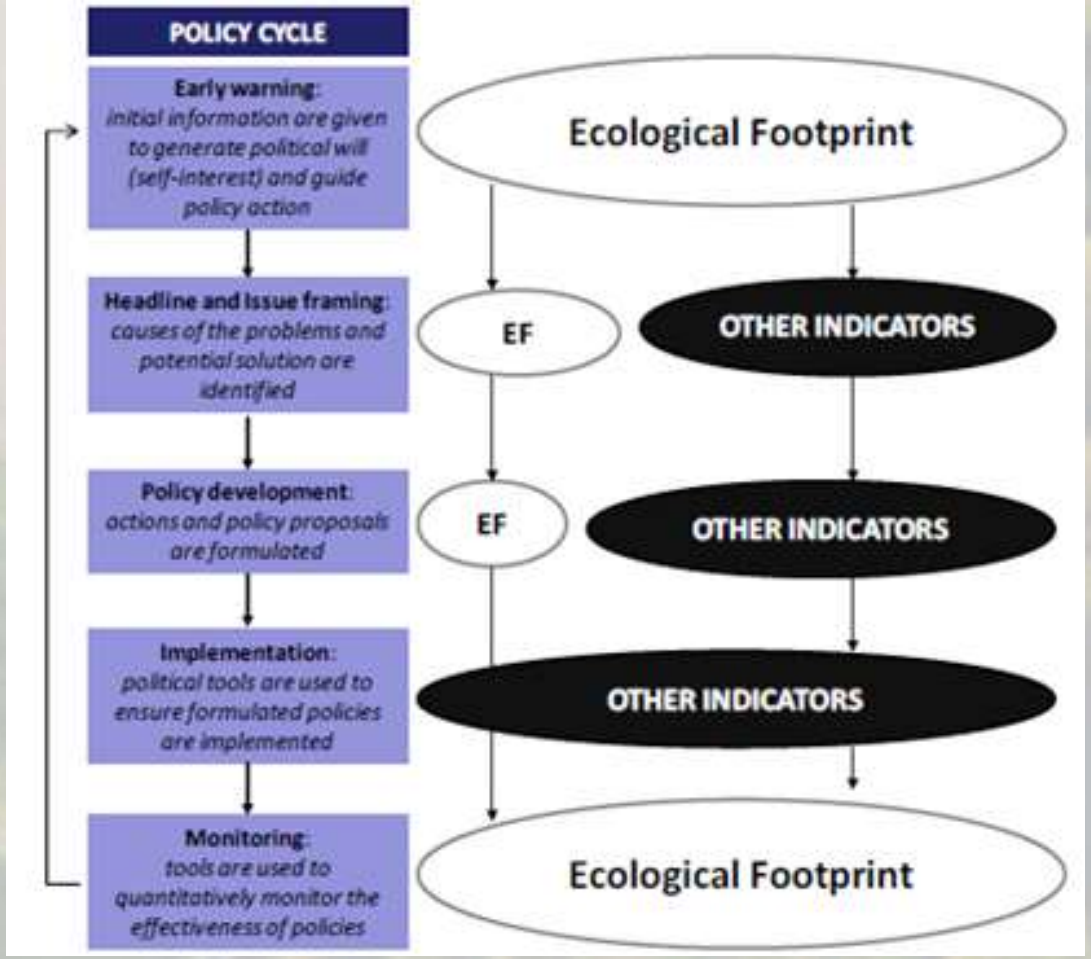
On the Usefulness of Ecological Footprint Accounting

§A systemic view is essential in dealing with sustainability (**Science**), but decisions and policies are implemented at national and local level (**Policy**).

§Multiple and diverse indicators are needed to track sustainability & bridge the science-policy gap.

§The role of indicators is not just providing numbers; they influence their users' approach and the wider political-institutional context (**pre-conditions for Sustainability Governance**).



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What do you think is the link between Ecological Footprint and the SDGs, if any?

Photo by Sveta Fedarava on Unsplash

Ecological Footprint and Multilateral Environmental Agreements (MEAs)

Indicator description

The Ecological Footprint compares human demand on nature against nature supply. Demand is measured in terms of the biologically productive areas – also called ecological assets – that a population requires for producing all the renewable resources it consumes and absorbing its waste. The availability of nature, called biocapacity, is also measured in surface area, and represents the availability of ecological assets and their regenerative capacity for such resources and waste. An increase in a nation's Ecological Footprint stands for an increase in its population's pressure on biodiversity and a greater risk of biodiversity loss.

Related SDGs

Expand

GOAL 8 - Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

GOAL 12 - Ensure sustainable consumption and production patterns.

Related Aichi Targets

Expand

Primary target

Target 4:
By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.

Other related MEAs and processes

Expand

IPBES Global Assessment Chapters

IPBES Regional Assessment Chapters

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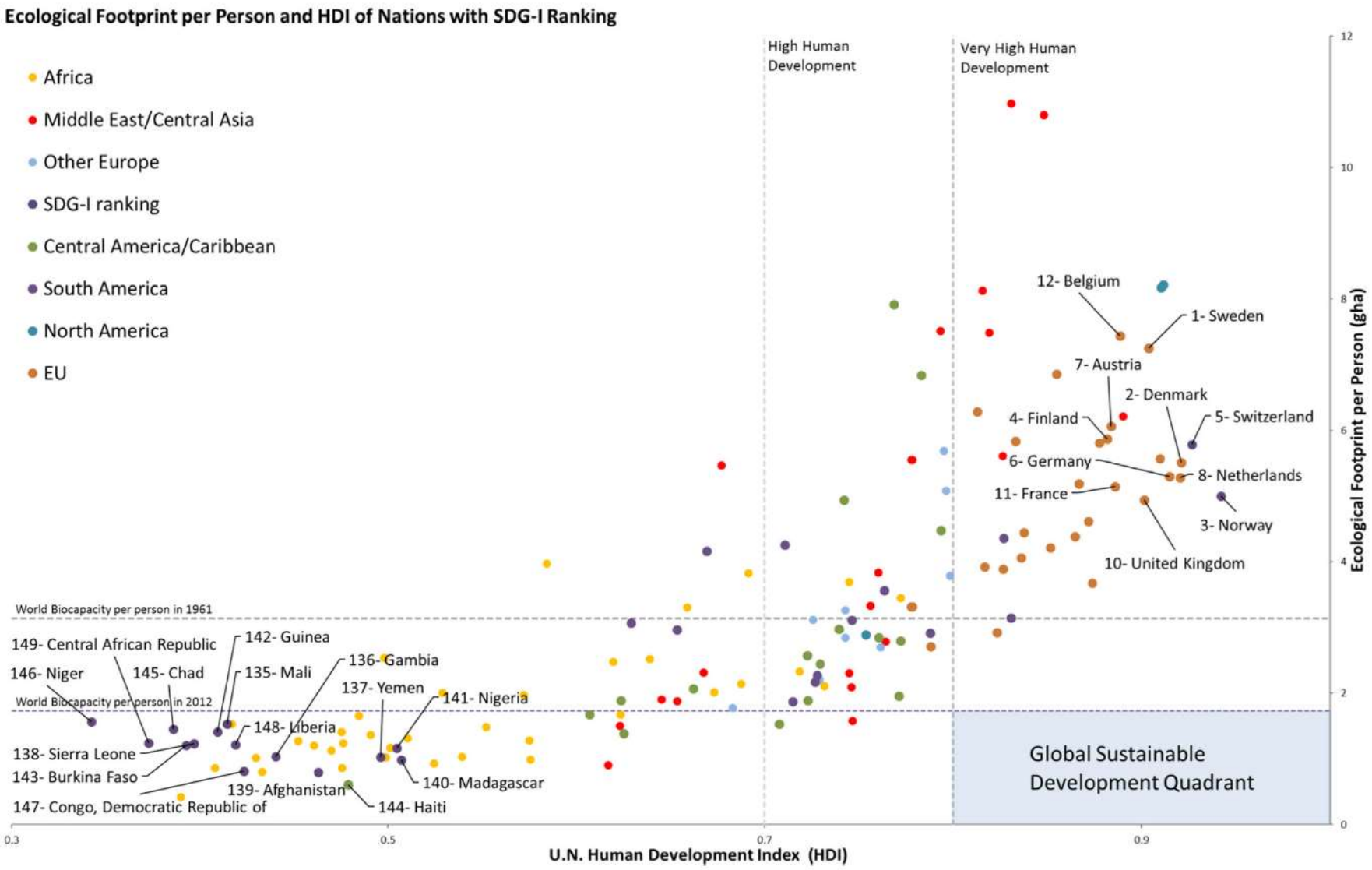

FIGURE 1 | Ecological Footprint per person and HDI by country indicate how close each country is to basic global sustainable development criteria (high human development, within resource requirements that are globally replicable). Each number indicates the country's ranking on the sustainable development goal (SDG) index (only top and bottom 10 are marked here).

NEW OPEN DATA PLATFORM

- In 2017 GFN has made for the first time **NFA results open** and available for download on the data website: http://data.footprintnetwork.org

PERSONAL FOOTPRINT CALCULATOR

https://www.footprintcalculator.org/

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There is not just a single Footprint!

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Existing Footprint Indicators: a list

- **1990s** - Ecological Footprint
- **Early 2000s** - Carbon Footprint
- **Early 2000s** - Water Footprint
- **2012** - Nitrogen Footprint: reactive nitrogen released in the environment because of individual consumption patterns.
- **2012** - Biodiversity Footprint: threats to species and habitat degradation due to human consumption activities.
- **2013** - accounting for the appropriation of land and raw materials as well as the release of chemical pollutants due to human activities:
  - Land Footprint
  - Material Footprint
  - Chemical Footprint
- **2014** - Inequality and Employment Footprint: tracks a country's consumption activities influence on income distribution and employment in other countries.
- Other with unclear def.
- **Early 2010s** - Footprint Family

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Introducing Footprint Indicators

- Footprint-type of indicators emphasize the analysis of human demand on Nature from a **consumer perspective**.
- These indicators are not based on who produces a good or service but on the end-users that consume them.
- Footprint indicators **easily communicate** the human use of the Earth's natural capital and have wide **range of applicability**

$$F_C = F_P + F_I - F_E$$

Footprint of Consumption | Footprint of Production | Footprint of Import | Footprint of Export

Trade analysis included

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Carbon Footprint

RESEARCH QUESTION	The total amount of greenhouse gas emissions (CO_2, CH_4, N_2O, HFC, PFC, and SF_6) that are directly and indirectly caused by human activities or accumulated over the life stages of products.
MAIN MESSAGE	The consumption-based perspective of the Carbon Footprint complements the production-based accounting approach taken by national greenhouse gas inventories (e.g., those considered by the Kyoto Protocol).

Carbon Footprint

- The six greenhouse gases identified by the Kyoto Protocol are included in the analysis:
  - CO_2, CH_4, N_2O, HFC, PFC, and SF_6
- Results are expressed in kg $CO_{2\text{-}e}$ and are calculated by multiplying the actual mass of a gas with the global warming potential factor for this particular gas, making the global warming effects of different GHGs comparable and additive
- The prevailing method for national Carbon Footprint accounting is environmentally extended multi-regional input-output analysis (EE-MRIO).

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Water Footprint

RESEARCH QUESTION	Human appropriation of natural capital in terms of the volume of freshwater required for human consumption.
MAIN MESSAGE	The Water Footprint concept is primarily intended to illustrate the hidden links between human consumption and water use and between global trade and water resources management.

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Water Footprint

Green water footprint

- volume of rainwater evaporated.

Blue water footprint

- volume of surface or groundwater evaporated.

Grey water footprint

- volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards.

Water Footprint

► total amount of water that is used to produce the goods and services consumed by the inhabitants of the nation.

► two components:

- internal water footprint – inside the country.
- external water footprint – in other countries.

► National water footprint =

national water use
+ virtual water import
– virtual water export

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Indicators: Instructions for use

- Indicators are communication tools that facilitate a simplification of the high complexity in human-environmental systems.
- An indicator is an integration of information, mainly extracted from direct measures, that helps represent a trend, a behavior or a threshold.
- **Indicators do not measure, they indicate**.
- The capacity of the human mind to simplify a complex situation in a compact characterization becomes dangerous when not controlled in terms of definitely stated criteria.
- With quantitative measurements especially, the definiteness of the result suggests, often misleadingly, a precision and simplicity in the outlines of the object measured.

Comparing the Indicators: unit of measure

ECOLOGICAL FOOTPRINT	CARBON FOOTPRINT	WATER FOOTPRINT
• Global hectares (gha) of bioproductive land. • gha is not a measure of area but rather of the ecological production associated with an area; • Results can also be expressed in actual physical hectares.	• Kg CO_2 when only CO_2 is included or kg CO_2-equivalent when other GHGs are also included; • No conversion to an area unit takes place to avoid assumptions and uncertainties.	• Water volume per unit of time (usually m^3 yr^{-1}) for the Water Footprint of processes; • m^3 ton^{-1} or liter kg^{-1} for the Water Footprint of products; • Water volume per unit of time for the Water Footprint of a geographical area.

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Comparing the Indicators: coverage

ECOLOGICAL FOOTPRINT	CARBON FOOTPRINT	WATER FOOTPRINT
• Temporally explicit and multi-dimensional indicator that can be applied to single products, cities, regions, nations and the whole biosphere. • More than 200 countries for the period 1961-2016 are tracked (Lin et al., 2018).	• Multi-dimensional indicator that can be applied to products, processes, companies, industry sectors, individuals, governments, populations, etc. • 73 nations and 14 regions for the year 2001 (Hertwich and Peters, 2009) • 113 countries for the year 2004 (Davis and Caldeira, 2010)	• Geographically explicit and multi-dimensional indicator: calculated for products, organizations, sectors, individuals, cities and nations. • 140 nations for the period 1996-2005 (Mekonnen and Hoekstra, 2010).

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Comparing the Indicators: strengths

ECOLOGICAL FOOTPRINT	CARBON FOOTPRINT	WATER FOOTPRINT
• **Allows benchmarking human demand with nature supply and determining clear targets.** • It provides a holistic assessment of multiple anthropogenic pressures. • Easy to communicate and understand with a strong conservation message.	• **It allows for a comprehensive assessment of human contribution to GHG emissions.** • It is consistent with standards of economic and environmental accounting.	• Represents the spatial distribution of a country's water "demand". • Expands traditional measures of water withdrawal (green and grey waters also included). • **Visualizes the link between (local) consumption and (global) appropriation of freshwater.** • Integrates water use and pollution over the production chain.

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Comparing the Indicators: weaknesses

ECOLOGICAL FOOTPRINT	CARBON FOOTPRINT	WATER FOOTPRINT
• **Cannot cover all aspects of sustainability,** neither all environmental concerns, especially those for which no regenerative capacity exists. • Shows pressures that could lead to degradation of natural capital (e.g. reduced quality of land or reduced biodiversity), but does not predict this degradation. • Not geographically explicit. • Some underlying assumptions controversial but documented.	• **Cannot track the full palette of human demands on the environment.** • Additional impact assessment models are needed to analyze the impact of climate change at both national and sub-national levels. • Efforts needed to set up and update a system of MRIO tables and related environmental extensions.	• **Only track human demands on freshwater.** • It relies on local data frequently unavailable and/or hard to collect. It suffers from possible truncation errors. • No uncertainty studies are available, though uncertainty can be significant. • Grey water calculation heavily relies on assumptions and estimations.

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Suggestions for further reading:

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- Ecological Footprint Explorer - GFN (http://data. footprintnetwork.org/#/) (**Optional**)
- Kitzes, J., & Wackernagel, M. (2009). Answers to common questions in Ecological Footprint accounting. *Ecological Indicators*, *9*(4), 812–817. https://doi.org/10.1016/j.ecolind.2008.09.014. (**Optional**)
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